N89-20693

Appendix A

View Graphs for GSFC Colloquium on OFMspert

October 1988

Human-Computer Interaction

in

Distributed Supervisory Control Tasks

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October 1988

Overview of Georgia Tech Activities

* Operator Function Model (OFM)

* GT-MSOCC (a research laboratory)

* Model-Based Operator Workstations

* Multi-Modal Operator Interaction

* OFMspert (Operator Function Model Expert System)

* Ally: OFMspert with Control Capabilities

* .Intelligent Tutoring System for Satellite Operators
  ITSSO and OFMTutor

TYPES OF APPLICATIONS

Complex, dynamic systems with high costs or risks associated with human error.

--space

--manufacturing

--process control and distribution systems

--military C2

Human operator functions as a supervisory controller

--monitors predominantly automated control systems

--fine tunes in response to unexpected changes in predicted system behavior

--fault detection, diagnosis, and compensation

EXPERIMENTAL ENVIRONMENT

MSOCC:
MULTISATELLITE OPERATIONS CONTROL CENTER

-Actual system at NASA/GSFC

- Coordinates use of shared computer and communications equipment

- System is now manual, moving towards automation

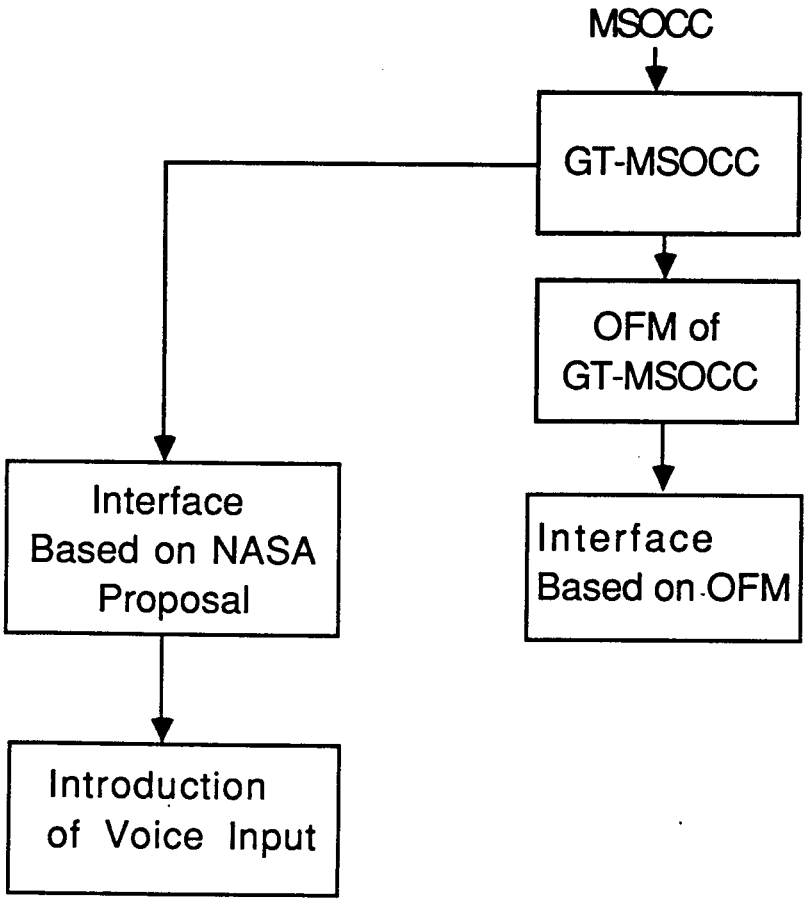
GT-MSOCC

- Developed at Georgia Tech

- Simulation of future automated MSOCC system

- Discrete event, Real Time, Interactive simulation

OVERVIEW OF GT-MSOCC RESEARCH



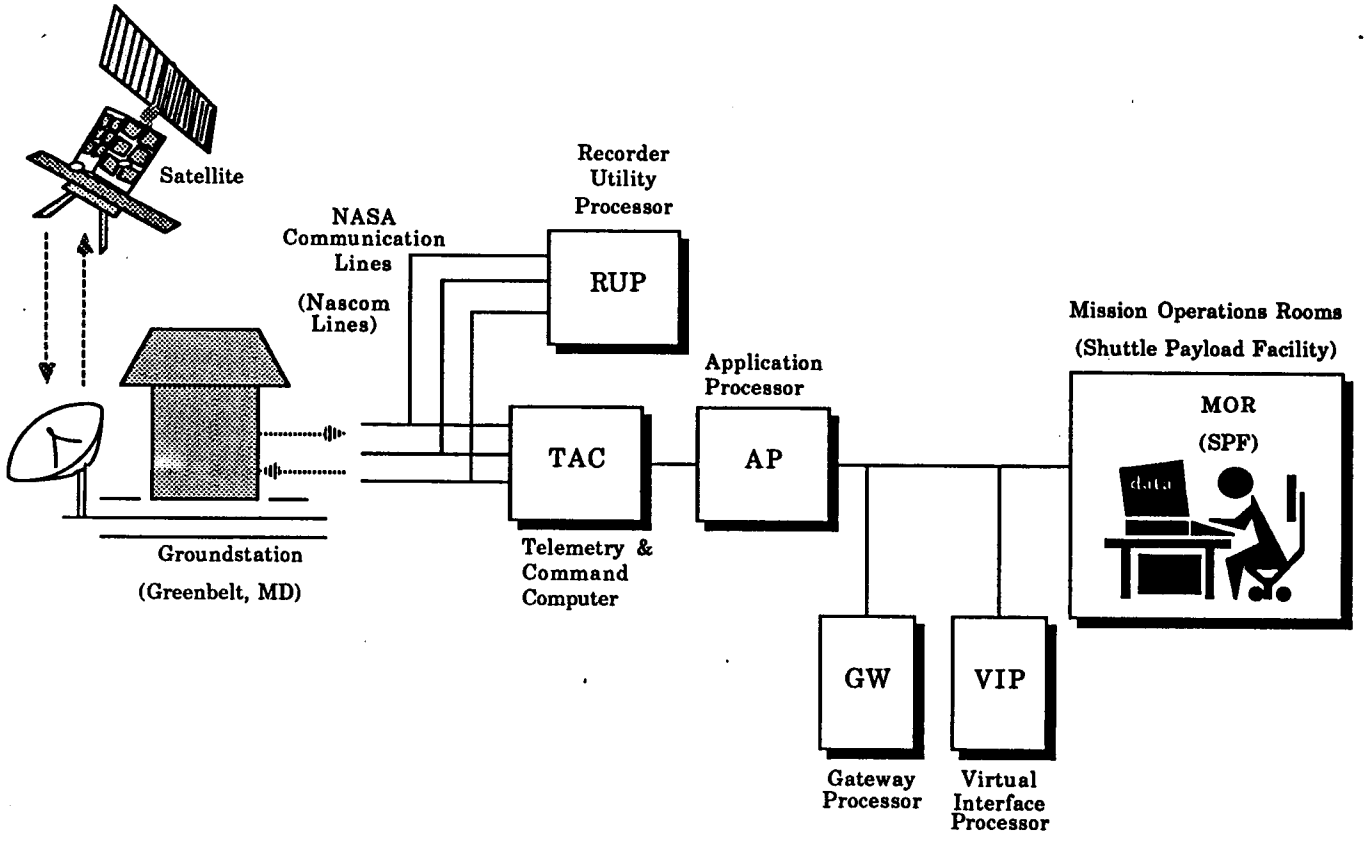


Figure 4. Multisatellite Operations Control Center

GT-MSOCC OPERATOR RESPONSIBILITIES

- SUPERVISE SPACECRAFT CONTACTS CURRENTLY BEING SUPPORTED

- COMPENSATE FOR AUTOMATED SCHEDULE PROBLEMS

- RESPOND TO REQUESTS FOR UNSCHEDULED SPACECRAFT CONTACTS

- DECONFIGURE ALL MANUALLY CONFIGURED EQUIPMENT STRINGS

Operator Function Model (OFM)

* a mathematical tool to represent operator interaction with predominantly automated space ground control systems (cognitive task analysis for system analysis and design).

* OFM's structure represents cognitive as well as physical operator tasks.

* useful for the design of operator workstations and displays (model-based iconic displays).

* useful for the design of an "intelligent" operator's associate (OFMspert and Ally).

* useful to represent the task knowledge in the design of an intelligent tutoring system (ITSSO and OFMTutor).

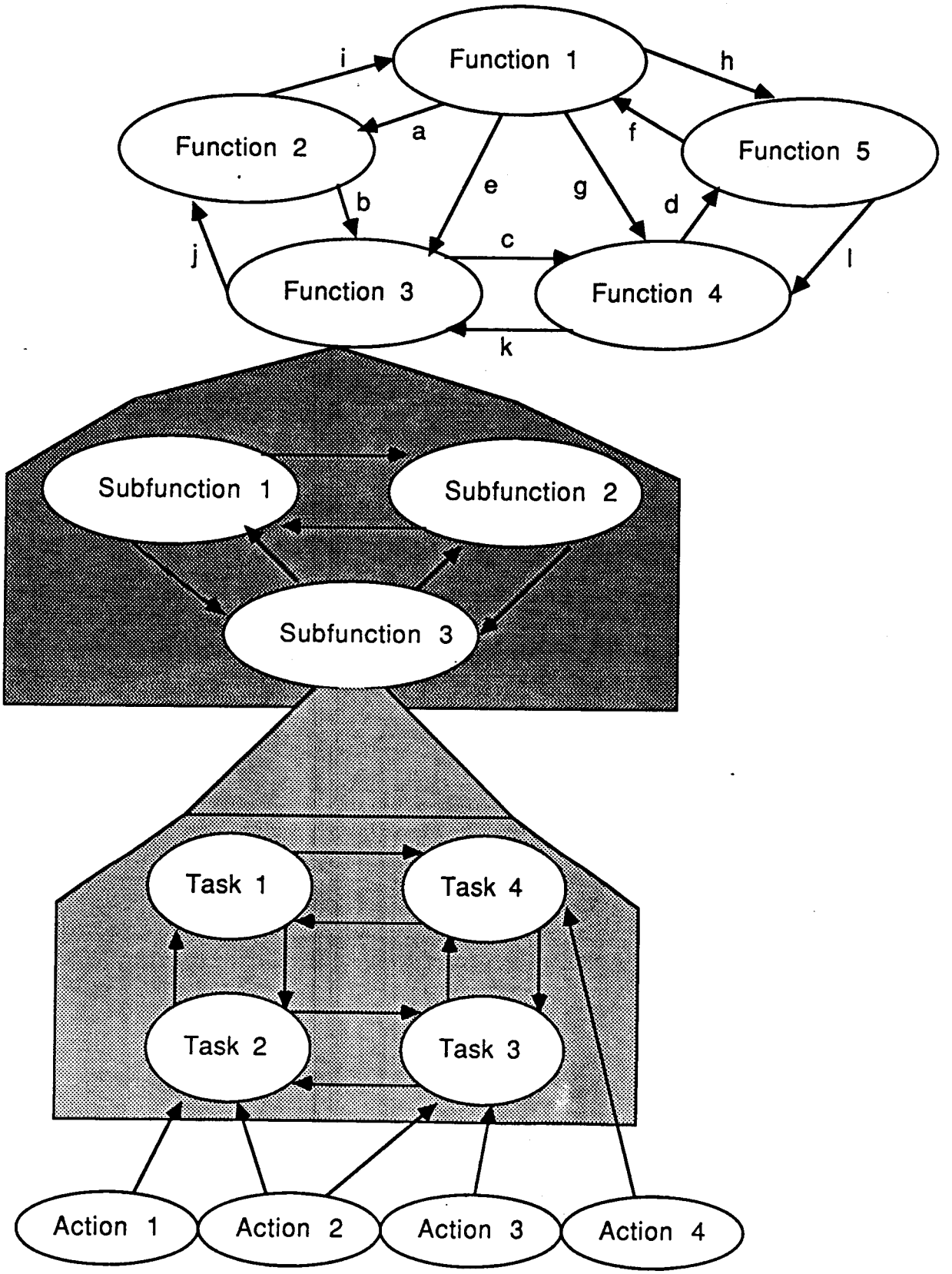


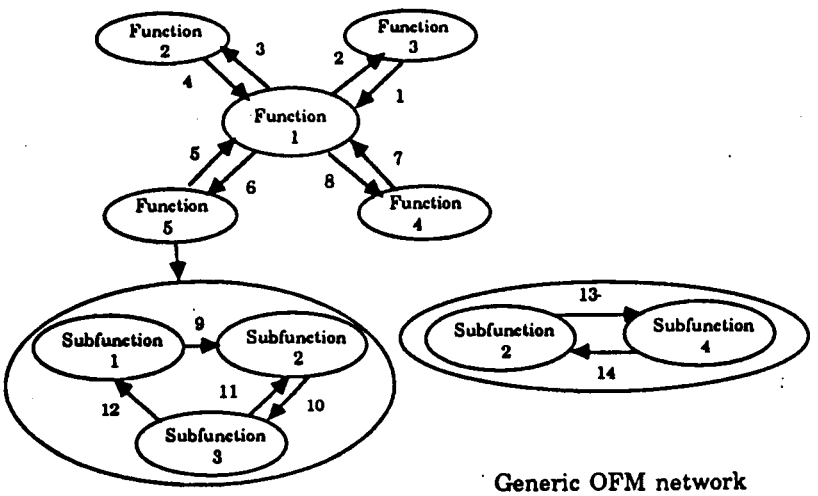
Figure 1. A Generic Operator Function Model

OFM STRUCTURE

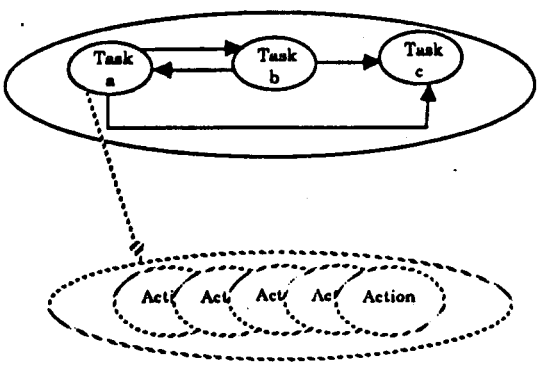
OFM is a network with nodes represented as non-deterministic, finite-state automata.

Higher level nodes represent operator goals; decomposition represents how operator coordinates control actions and system configuration so that acceptable overall system performance is reached.

Next-state transition functions model system triggering events



Generic OFM network



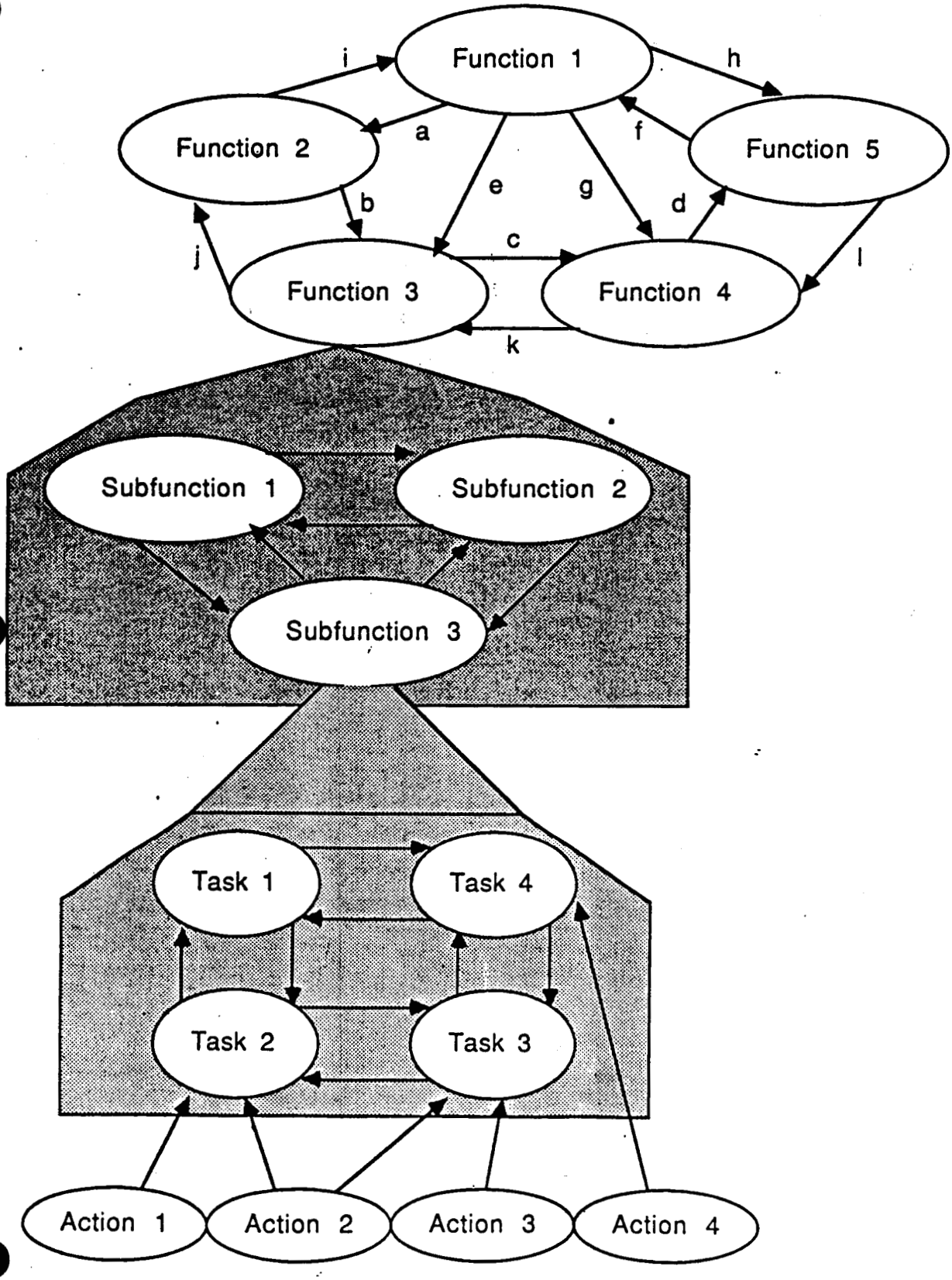
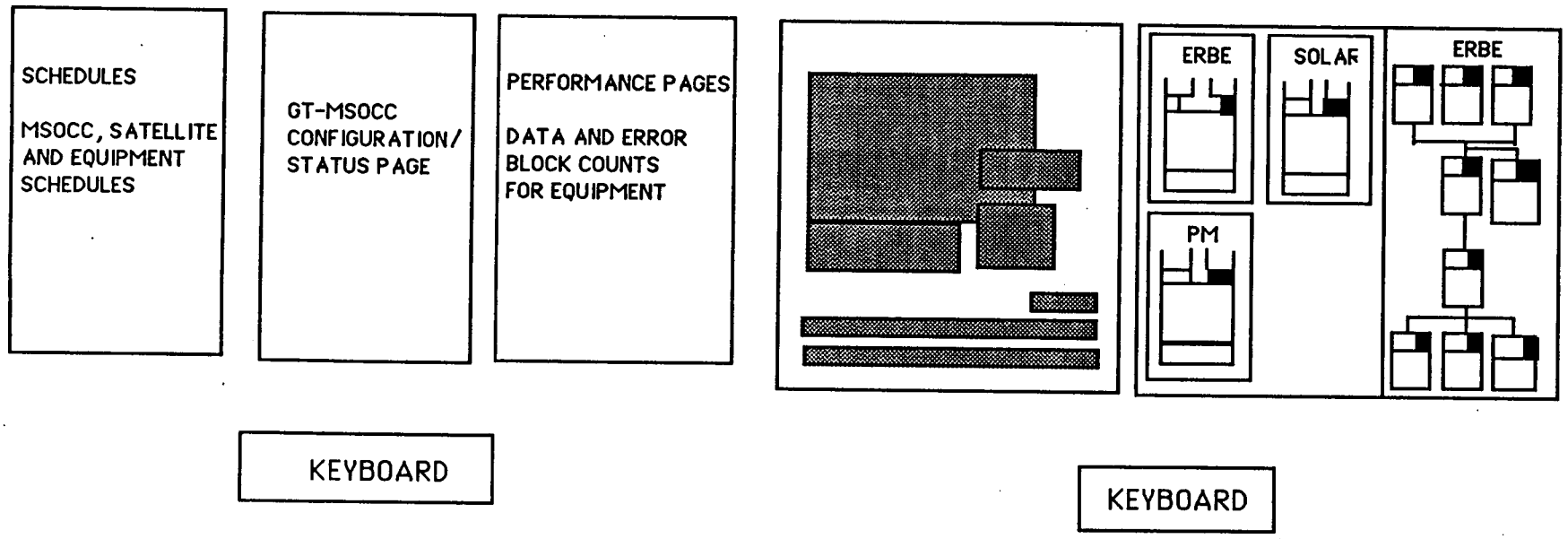


Figure 2. A Generic Operator Function Model



CONVENTIONAL WORKSTATION → MODEL-BASED WORKSTATION

Primary Features of OFM-Based Interface

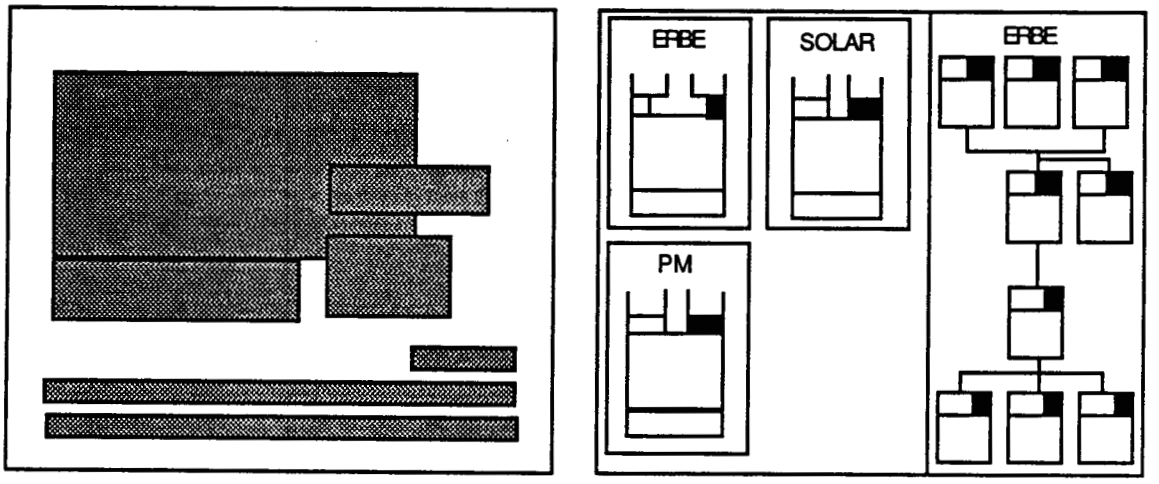
DYNAMIC ICONS

- Qualitative Representation
- High Level View of System Functioning
- Detailed View of Data Propagation

COMPUTER WINDOWS

- Alphanumeric, Overlapping Windows
- Contents Determined by OFM
- Placement Determined by OFM

TWO-MONITOR OFM-BASED INTERFACE



KEYBOARD

EXPERIMENTAL DESIGN

10 SUBJECTS USED EACH INTERFACE

12 EXPERIMENTAL SESSIONS (45 MINUTES EACH)

- 5 TRAINING SESSIONS
- 7 SESSIONS FOR DATA ANALYSIS

INDEPENDENT MEASURES

- DISPLAY CONDITION
- SESSION
- SUBJECT

DEPENDENT MEASURES

- FAULT COMPENSATION (4 MEASURES)
- EQUIPMENT CONFIGURATION AND DECONFIGURATION (5 MEASURES)
- OPERATOR ERROR (2 MEASURES)

Operator Performance Measures

Time to fix system problems:
--fix hardware failures.
--fix each of 3 software failures.
--compensate for automated schedule problems.
--deconfigure manually configured equipment

Number of operator errors:
--operator caused schedule conflicts.
--unnecessary equipment replacements.

Time to respond to ad hoc requests for equipment.

Accuracy of response to ad hoc requests.

MEAN SCORES PER SESSION

MEASURES	ICON/WINDOWS	KEYBOARD	VOICE
Time to detect hardware failures	42.5s*	56.4s	88.0s*
Time to detect SW no flow	56.9s*	312.4s	369.4s
Time to detect SW decreased flow	71.2s*	398.9	438.9s
Time to detect high error count	206.0s*	356.7s	391.7s
Time to deconfigure	11.1s*	22.6s	28.0s
Time to compensate for automated schedule problems	46.5s	75.9s	82.9s
Number of operator-caused schedule conflicts	.16*	.70	.93

MEAN SCORES PER SESSION

MEASURES	ICON/WINDOWS	KEYBOARD	VOICE
# of Unnecessary Replacements	.23*	1.13	1.14
Good Displays Called		45.5	24.5*
Bad Displays Called		2.5	1.1*

THE AUDOPILOT VOICE INTERFACE

- Isolated word, single user recognition
- Template-matching algorithm
- Three background noise levels
- Hierarchical vocabularies
- Up to 64 words per vocabulary
- Manufacturer-reported 98% accuracy
- Desk-top microphone